

The Canadian Encyclopedia

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Nuclear Power Plants

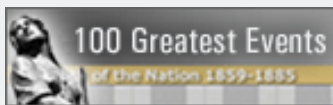
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Canada's First Nuclear Reactors

The NRX reactor, the ancestor of Canada's unique CANDU reactors, "went ... [More](#)

CANDU Reactors

To make fuel pellets for a CANDU reactor, the uranium dioxide is compressed, then baked at high temperatures to yield hard, insoluble, ceramic cylinders about 14 mm in diameter by 20 mm long. To make one fuel element, a 500 mm long stack of pellets is loaded into a metal tube (made of the zirconium alloy, Zircaloy), which is sealed at each end by welding. For present CANDU reactors 37 elements are assembled by further welding to form a fuel bundle, with individual elements held apart from each other. This fuel bundle is the first basic building block for the reactor. Uranium is a very concentrated energy source. A fuel bundle 500 mm long, 100 mm in diameter and weighing 22 kg could be carried in an overnight bag. When put in a CANDU reactor, it can produce as much ENERGY as burning about 400 t of coal or 2000 barrels of oil.

In the reactor, 12 bundles are placed end-to-end in a tube through which water coolant is pumped. Since the water is at nearly 300°C, it develops a pressure of about 100 atmospheres; the tubes are therefore known as pressure tubes. Each pressure tube, with its contained fuel and coolant and with end fittings to get the coolant in and out, constitutes a fuel channel, the next larger building block for a CANDU reactor. The reactor core consists of several hundred fuel channels positioned in a carefully calculated grid and passing horizontally through a tank, or calandria, containing heavy water as a moderator. Heavy water is a compound of hydrogen and oxygen, having a higher proportion of the heavy hydrogen isotope deuterium than does natural water. The presence of the heavy water and the particular arrangement of channels are essential for fission to occur in the uranium. This arrangement contributes to the safety of the reactor: if the reactor were to be seriously damaged one or both of these conditions would probably be affected and the fission process would stop automatically. This is an example of what is known as a fail-safe feature.

The coolant from the fuel channels is piped to steam generators, where the heat from the fuel is used to boil water in a secondary circuit. The resulting steam drives the turbine and turns the generator to produce electricity. The reactor coolant, now at a lower temperature, circulates back to the reactor in the closed primary circuit.

When a fuel bundle has to be replaced (after about a year and a half in the reactor), remotely controlled fuelling machines are clamped to each end of its fuel channel. Fresh fuel is pushed in from one end and the used fuel is deposited in the machine at the other end. A used fuel bundle, which looks much the same as a fresh one, retains all its wastes sealed within it. Used bundles are stored in a water-filled tank, like an extra-deep swimming pool, in a building adjacent to the reactor. The water cools the bundles and absorbs the radiation they emit. The ability to change fuel without having to shut down the reactor makes the CANDU design unique among current commercial reactors, and contributes to their exceptionally high capacity factors, ie, the electricity actually generated during some period, expressed as a percentage of what is theoretically possible.

To control the power level of the reactor, control rods are moved into or out of the reactor core. They are contained in tubes which penetrate the top of the calandria and pass between fuel channels. A reactor control system is used much as is an accelerator in controlling the speed of a car. However, unlike the car's accelerator, the control rods in the reactor can also bring things to a stop, ie, shut down the chain reaction. In addition to control rods there are 2 independent systems, each capable of shutting down the reactor quickly. These can be compared to 2 independent braking systems in a car, although the shutdown systems, unlike brakes, are neither needed nor used in normal operation. They are called upon only if some other system fails. One type consists of rods similar to control rods but capable of being inserted into the reactor core more rapidly; the other consists of perforated horizontal tubes in the calandria through which a liquid can be squirted into the heavy-water moderator. Control rods and shutdown systems both work by introducing into the reactor materials (eg, cadmium or gadolinium) that absorb neutrons strongly. Adding absorbers slows down, then stops the fission chain reaction; withdrawing them allows the reaction to start up again.

The fuel in an operating reactor (and even when discharged) is highly radioactive, ie, it emits gamma radiation similar to medical X rays. To protect the station operators, the reactor core is surrounded by heavy shielding, typically of reinforced concrete about 1 m thick. To protect the public against the possibility of radioactive releases which might occur in the event of an accident, the whole reactor and its primary coolant circuit are located within a sealed containment building, a massive concrete structure. No dwellings are allowed within a radius of about 1 km; thus any escaping radioactive material would be diluted and dispersed before reaching the public.

